§27. Formation of Symmetric Stellarator Configurations Based on Plasma Boundary Modulations

Yokoyama, M., Nakajima, N., Okamoto, M.

For considering the innovative concepts of stellarator configurations, it is essential to handle the magnetic field properties for desired physical requirements. The magnetohydrodynamic (MHD) equilibrium can be uniquely specified by the shape of the plasma boundary. Therefore, basic roles of several principle modulations of the plasma boundary shape on MHD equilibria have been investigated.

The principal helical modulations give the variation of area of magnetic surface cross sections along the toroidal direction. This variation causes the relatively large bumpy field component (B_{01}) due to the magnetic flux conservation, which is not appropriate for realizing quasi-axisymmetric (QAS) or quasi-helically symmetric (QHS) configurations. The appropriate combination of principle helical modulations to suppress B_{01} is considered.

The triangular modulations can be utilized to form or deepen the magnetic well by shifting the magnetic axis outward compared to the center of mass of magnetic surface cross section. The favorable radial triangular modulation gives the indented cross section around $\phi \sim 0$ and the favorable vertical one leads to the outward pointing triangular (or D-shape) cross section around $\phi \sim (1/2)(2\pi/M)$, which are frequently seen in the W7-X, QAS and QHS configurations. Here ϕ denotes the geometrical toroidal angle and M the number of the field period. The possibility of global magnetic shear control by the triangular modulations is also considered.

The bumpy modulations or the spatialization of the magnetic axis is also investigated. The significant feature of bumpy modulations is that the toroidicity in the magnetic field (B_{10}) is effectively reduced as the magnetic axis excursion is enhanced. This is utilized in the HSX to realize a QHS configuration and also in the W7-X to reduce B_{10} to about half of geometrical inverse aspect ratio. The required magnetic axis excursion depends on M: the larger excursion is required as M is decreased because B_{10} becomes relatively larger compared to helical fields.

The possibility of a quasi-bumpy (or poloidally) symmetric (QBS) configuration is also considered. The variation of magnetic surface cross sectional area in the toroidal direction causes the large B_{01} with either sign. By utilizing this, the magnetic field with B_{01} dominantly is possible. This configuration has a finite ι, and therefore, it is distinguishable from the so-called bumpy torus.

As for reference, examples of magnetic surface cross sections on three poloidal cross sections for the obtained QAS, QHS and QBS configurations are shown in Fig. 1.

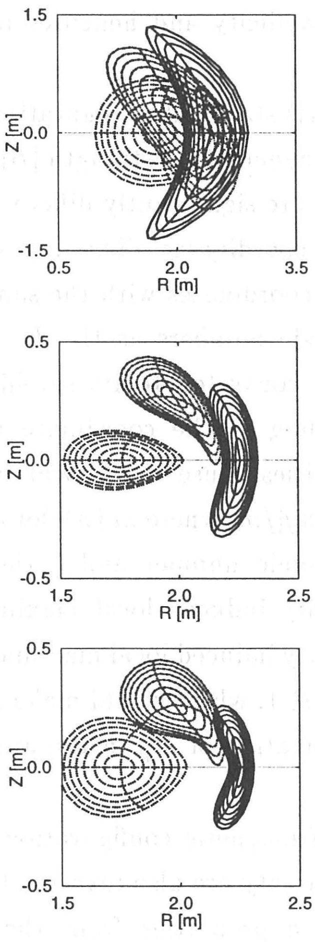

Fig. 1 Obtained magnetic surface cross sections for example QAS, QHS and QBS (from top to bottom) stellarator configurations.